Building Research Establishment Digest

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Mortars for bricklaying

The recommendations for mortar mixes and their suitability for various locations and conditions, previously given in Digest 58, have been revised to bring them into line with those of CP 121:Part 1:1973 'Brick and block masonry', BS 187:Part 2:1970 'Calcium silicate (sandlime and flintlime) bricks' and BS 1180:1972 'Concrete bricks and fixing bricks'.

Digest 58 is now withdrawn.

A good mortar hangs on the trowel and spreads easily. It does not readily lose water and stiffen in contact with absorptive bricks. It remains plastic long enough for the bricks to be easily adjusted to line and level. These properties help to develop a good bond between bricks and mortar and lessen the risk of rain penetration through the finished wall.

Mortar must be able to resist frost, and it should develop its durability fairly quickly, particularly in winter. This implies early development of strength, though other factors besides strength contribute to durability and it is certainly not justifiable to assume that 'the higher the strength the better the mortar'.

Types of mortar

Lime mortar

Traditional lime mortar is made from lime and sand. For workability, voids between the sand grains need to be filled with the binder paste. This requires about one volume of lime for every three of sand.

Lime mortars made from high-calcium limes have good working qualities, especially if the lime is prepared by running quicklime to a putty, but develop strength very slowly. They do not 'set' but stiffen as they lose water by absorption into the units and by evaporation; further gain in strength is acquired by very slow reaction with carbon dioxide from the air. For this reason they are rarely suited to present-day needs.

Cement mortar

Adequate strength in fully-hardened mortar, with rapid development of strength in the early stages, is most conveniently obtained by using Portland cement. About one volume of cement is needed for three volumes of sand to give a workable mix. Cement:sand mixes in the proportion 1:3 are appropriate for work subjected to high stress and made with units of appropriate strength. They may be used in foundations and below the level of the damp-proof course to give a dense mortar which, because of its impervious nature, is likely, in wet conditions, to be more resistant to the effects of soluble salts.

A mortar of this kind is too strong for most other purposes but it is not practicable to adjust the strength simply by varying the ratio of cement to sand, because lean mixes of cement and sand are harsh and unworkable.

Cement-lime (compo) mortar

Mortars made with appropriate proportions of Portland cement, including sulphate-resisting Portland cement, and lime take advantage of the useful properties of each. Cement:lime:sand mortars are designed by replacing part of the cement in a 1:3 cement mortar by an equal volume of lime so that the binder paste still fills the voids in the sand. In this way, good working qualities, water retention, bonding properties and early strength can be secured without the mature strength being too high.

Air-entrained (plasticised) mortar

Mortar plasticisers, which entrain air in the mix, provide an alternative to lime for improving the working qualities of lean cement:sand mixes. In effect, the air bubbles increase the volume of the binder paste and help to fill the voids in the sand.

Masonry cement mortar

Masonry cements consist of a mixture of Portland cement with a very fine mineral filler and an air-entraining agent. Their working properties derive from the plasticising effects of the fine material and the entrained air. The manufacturers' instructions should be closely followed.

Mortars made with special cements

High alumina cement (BS 915:Pt 2:1972) may be used where high early strength or resistance to chemical attack is required. Sulphate-resisting Portland cement (BS 4027:Pt 2:1972) or high alumina cement improve the resistance to sulphate attack, but high alumina cement should not be used where it will be both moist and above 30°C for long periods.

Lime must not be used with high alumina cement; lean mortars made with this cement can be plasticised instead with ground chalk or limestone, or with suitable, non-alkaline, air-entraining mortar plasticisers.

Sulphate-resisting Portland cement can be substituted for ordinary Portland cement in the same proportions although the effect on the sulphate-resistance of the leaner mortars may be negligible; there is evidence that aerated cement:sand mortars are more resistant to sulphate attack than cement:lime:sand mortars of the same strength designation.

Selection of mortars

In Table 1, mortars are designated (i)–(v) according to the type of construction for which they are suitable.

Table 2 assists in the choice of a mortar from within any one designation by indicating how the mixes compare in strength and resistance to frost and rain penetration. The guiding principle in using these Tables is that the mortar used should contain no more cement than is necessary to give adequate strength in the brickwork, unless there is good reason for choosing a richer mix. Loading tests on walls and piers have shown that the strength of mortar has less influence on the strength of brickwork than might be supposed, but the strength achieved with masonry cement or plasticised mortars may be lower than that of 1:$\frac{1}{2}$:4–4$\frac{1}{2}$ cement:lime:sand and for calculated load-bearing brickwork they should not be regarded as equivalent.

In winter, the richer mortars are preferred because they quickly develop strength enough to resist the effects of frost. Richer mortars may also be desirable for exposed work with bricks that contain appreciable quantities of soluble sulphates (*see* Digest 89).

An unnecessarily strong mortar concentrates the effects of any differential movement in fewer and wider cracks; a weaker mortar will accommodate small movements and any cracking will be distributed as hair cracks in the joints, where they are less noticeable. The stresses resulting from restraint of any expansion of bricks are reduced if a relatively weak mortar is used. The choice may entail risk of frost damage and precautions should be taken to protect work in cold weather (*see* 'Cold weather bricklaying').

Table 1 Selection of mortar groups

Type of brick:	Clay		Concrete and calcium silicate	
Early frost hazard[a]	no	yes	no	yes
Internal walls	(v)	(iii) or (iv)[b]	(v)[c]	(iii) or plast(iv)[b]
Inner leaf of cavity walls	(v)	(iii) or (iv)[b]	(v)[c]	(iii) or plast(iv)[b]
Backing to external solid walls	(iv)	(iii) or (iv)[b]	(iv)	(iii) or plast(iv)[b]
External walls; outer leaf of cavity walls:				
—above damp-proof course	(iv)[d]	(iii)[d]	(iv)	(iii)
—below damp-proof course	(iii)[e]	(iii)[b, e]	(iii)[e]	(iii)[e]
Parapet walls; domestic chimneys:				
—rendered	(iii)[f, g]	(iii)[f, g]	(iv)	(iii)
—not rendered	(ii)[h] or (iii)	(i)	(iii)	(iii)
External free-standing walls	(iii)	(iii)[b]	(iii)	(iii)
Sills; copings	(i)	(i)	(ii)	(ii)
Earth-retaining walls (back-filled with free-draining material)	(i)	(i)	(ii)[e]	(ii)[e]

a during construction, before mortar has hardened (say 7 days after laying) or before the wall is completed and protected against the entry of rain at the top

b if the bricks are to be laid wet, *see* 'Cold weather bricklaying'

c if not plastered, use group (iv)

d if to be rendered, use group (iii) mortar made with sulphate-resisting cement

e if sulphates are present in the groundwater, use sulphate-resisting cement

f parapet walls of clay units should not be rendered on both sides; if this is unavoidable, select mortar as though *not* rendered.

g use sulphate-resisting cement

h with 'special' quality bricks, or with bricks that contain appreciable quantities of soluble sulphates.

Materials

Sand: Sand should be to BS 1200:1955. Where very fine sands are used, the proportion of sand should be reduced as indicated in the note to Table 2, but they should not be used for calculated load-bearing brickwork.

Lime: Non-hydraulic and semi-hydraulic (calcium) limes and magnesian limes should be to BS 890: 1966. The standard does not cover eminently hydraulic limes. These develop strength reasonably quickly; they give good service in the hands of those who are familiar with them and know by experience how to slake and handle them.

Cement: Portland cement and rapid-hardening Portland cement (BS 12:Pt 2:1971), Portland blast-furnace cement (BS 146:1958) and sulphate-resisting Portland cement (BS 4027:Pt 2:1972) may be mixed with lime; high alumina cement may not, though it may be mixed with an inert filler, such as ground chalk, to improve workability.

Admixtures: Mortar plasticisers should meet the requirements of BS 4887:1973 *Mortar plasticisers.* Water-retaining agents may be used if the manufacturer provides evidence of their suitability.

Gauging and mixing

The care taken to select the best mix proportions will be largely nullified if the materials for the mix are 'measured' by the shovelful instead of in gauge boxes, or if no allowance is made for the increase in volume of sand when it is damp. Thus, 7 volumes of damp sand may be equivalent to only 5 volumes of dry sand.

Weigh-batching will permit the highest level of control but if the materials are to be batched by volume separate gauge boxes should be provided for each of the materials; their sizes should be so related that they are used only filled to capacity and struck off level. It is a further advantage if the sizes of gauge box are designed for use with whole or half-bags of cement.

The error introduced by bulking of sand is reduced in cement:lime:sand mixes if the mortar is prepared from lime/sand coarse stuff because the volume of the wet coarse stuff is about equal to that of its sand content when dry; the lime occupies only part of the void space in the sand, the cement filling the remainder. For example, one volume of cement can occupy the void space in six volumes of a 1:6 lime:sand mix to give six volumes of 1:1:6 mortar (*see* Table 3).

The gauging of coarse stuff is better than preparing a mixture of cement, dry hydrated lime and sand because the lime becomes more plastic if it is soaked in water before use. Where the dry hydrate is used, the working properties of the mortar can be improved by increasing the proportion of lime by up to 50 per cent.

The development of strength in cement:sand or cement:lime:sand mixes depends on the cementitious properties of the cement and these will be largely lost if the mixed mortar is allowed to stand too long and is knocked up again after the cement has begun to set. Mixes should be prepared in batches of a size that can be used up within about two hours; any surplus should then be discarded.

Gypsum plaster must never be added to mixes containing Portland cement because such mixes expand under moist conditions.

When mixing plasticised cement:sand mortars or masonry cement mortars, care should be taken not to add too much water at the start, as these mortars become more fluid as air is entrained.

All types of mortar can be mixed satisfactorily by hand on a banker, but mechanical mixers must be carefully selected and controlled. The old-fashioned roller type of mortar mill is not suitable for aerated mortars because it does not entrain sufficient air. Prolonged mixing of these mortars in other types of mixer can lead to excessive air entrainment and unduly weak mortars, unless the plasticiser is known to be of the neutralised vinsol resin type and care is

Table 2 Mortar mixes (proportions by volume)

	Mortar group	Cement : lime : sand	Masonry-cement : sand	Cement : sand, with plasticiser
Increasing strength but decreasing ability to accommodate movements caused by settlement, shrinkage, etc	i	1 : 0–¼ : 3	—	—
	ii	1 : ½ : 4–4½	1 : 2½–3½	1 : 3–4
	iii	1 : 1 : 5–6	1 : 4–5	1 : 5–6
	iv	1 : 2 : 8–9	1 : 5½–6½	1 : 7–8
	v	1 : 3 : 10–12	1 : 6½–7	1 : 8

Direction of changes in properties:
- equivalent strengths within each group
- increasing frost resistance
- improving bond and resistance to rain penetration

Where a range of sand contents is given, the larger quantity should be used for sand that is well graded and the smaller for coarse or uniformly fine sand.

Because damp sands bulk, the volume of damp sand used may need to be increased. For cement:lime:sand mixes, the error due to bulking is reduced if the mortar is prepared from lime:sand coarse stuff and cement in appropriate proportions; in these mixes 'lime' refers to non-hydraulic or semi-hydraulic lime and the proportions given are for lime putty. If hydrated lime is batched dry, the volume may be increased by up to 50 per cent to get adequate workability.

Table 3 Cement:lime/sand mixes for specified cement:lime:sand mix proportions (1)

Mortar group	Specified cement:lime:sand proportions	Site-mixed coarse stuff		Ready-mixed lime:sand for mortar (BS 4721)		
		Lime-putty:sand	cement:coarse stuff	Category of lime/sand mix	Cement:lime/sand mix (2) normal use	special use
(i)	1:¼:3	1:12	1:3	1:12	1:3	—
(ii)	1:½:4–4½	1:8–9	1:4–4½	1:9	1:4½	1:4
(iii)	1:1:5–6	1:5–6	1:5–6	1:6	1:6	1:5
(iv)	1:2:8–9	1:4–4½	1:8–9	1:4½	1:9	1:8
(v)	1:3:10–12	1:3½–4	1:10–12	1:4	1:12	1:10

(1) The proportions stated throughout this table are by volume.

(2) The proportions given for normal use result in mortars with the higher sand content of the specified mix proportions; if difficulty is experienced in attaining satisfactory strength, the proportion of cement:lime/sand mix may be increased up to that shown for special use which results in the lower sand contents of the specified mix proportions.

taken not to exceed the correct dosage. However, prolonged mixing of cement/lime mortars tends to improve their plasticity and water retention, and a further improvement can be obtained by the use of high-speed mixers or activators.

Ready-mixed lime/sand

Table 3 shows a range of ready-mixed lime/sand wet mixes (col 5) to be gauged only with cement and additional water to produce cement:lime:sand mortars of the proportions stated in col 2. A lime/sand mix should be kept for at least 16 hours before use, to enhance its workability.

For most work, the lime/sand mix and the cement can be batched accurately enough by volume, but it is essential to provide separate containers for each. Batching the cement by weight will give closer control of the quality of the mortar.

Coloured mortars

Any pigments used should meet the requirements of BS 1014; white cement, which may be needed for use with some pigments, is covered by BS 12. Coloured cements, also covered by BS 12, are basically white or ordinary Portland cement to which five to ten per cent of pigment has been added, usually at the grinding stage, and are likely to give more even distribution of colour throughout the mortar mix (and throughout the job) than is possible by adding pigment at the mixer. Where strength or bond are important, the quantity of pigment should not exceed ten per cent of the weight of the cement (or for carbon black, which is not covered by BS 1014, about three per cent).

It may be necessary, also, to agree special requirements for the colour and uniformity of colour of the sand to be supplied throughout the contract.

Jointing and pointing

Jointing as the work proceeds is preferable to pointing, but if the work is pointed as a separate operation the mix used should not be appreciably stronger than the bedding mortar. Old brickwork should be repointed with mortar containing no more cement than is necessary to give adequate resistance to weathering.

Cold weather bricklaying

Bricks should be kept off the ground, stacked and protected by a waterproof cover; precautions should be taken with sand to avoid the inclusion of ice particles. In severe frosts, both materials and mixing plant should, if possible, be stored in heated sheds (see *Winter building*; HMSO: 1963).

Table 1 recommends the mortar groups that are preferred for use when there is a risk of frost during or shortly after construction and Table 2 indicates the relative frost resistance of similar strengths of mortars within each group. If the bricks are unavoidably wet when laid, a plasticised cement:sand mortar is preferred. Alternatively, a masonry cement:sand mortar may be used, or the resistance to damage by freezing of cement:lime:sand mortars may be improved by adding a plasticiser and ensuring that the air content of the mortar is 8–12 per cent when used. Calcium chloride, or additives based on this salt, do not prevent frost damage to mortars; their use introduces the risks of corrosion of embedded metals, eg wall ties, and of permanent dampness in the finished work.

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